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SU(3) Symmetry In Electron-Positron Annihilation

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ABSTRACT

Exact SU(3) predicts equal production of $\pi^+\pi^-$ and K^+K^- final states, while $K^0\bar{K}^0$ is forbidden as a result of cancellation between isovector and isoscalar photon contributions. Symmetry breaking destroys coherence between ρ-, ω- and ϕ like photon components. Branching ratios $\pi^+\pi^-/K^+K^-/K^0/\bar{K}^0$ calculated under various coherence assumptions give different results. Experimental measurements should test this interference and give insight into the role of photon SU(3) structure in deep annihilation.

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The assumption of SU(3) symmetry in e^+e^- annihilation processes leads to interesting predictions for the case of two-meson final states. Cross sections for annihilation into two charged pions and into two charged kaons are equal,

$$\sigma(e^+e^- \to K^+K^-) = \sigma(e^+e^- \to \pi^+\pi^-) \tag{1a}$$

annihilation into two neutral kaons is forbidden!

$$\sigma(e^+e^- \to K^0\overline{K}^0) = 0 \tag{1b}$$

These predictions follow simply from U spin.[1] The photon is a U spin scalar; the $\pi^+\pi^-$ and K^+K^- states are a U spin mirror pair and must be equally produced from a scalar initial state. The selection rule against neutral kaon pair production is seen from the U-spin analog of G parity, under which the neutral kaons are odd and the photon is also odd. This selection rule is the U-spin analog of the G parity selection rule forbidding the $\omega \to 2\pi$ decay. An SU(3) rotation which transforms isospin into U spin takes the isoscalar ω into the U-spin scalar photon and the isovector charged pions into the U-spin vector neutral kaons.

The failure of these striking predictions to agree with experiment below 1 GeV is due to obvious SU(3) symmetry-breaking mechanisms. At low energies, annihilation is dominated by production[2] of the vector mesons ρ, ω and ϕ. In the SU(3) symmetry limit the three states are degenerate and the two-kaon channel is either open or closed for all of them. In the real world the two-kaon threshold is at 988 MeV and only pions are observed below these energies. The two-kaon channel is open only for the ϕ and closed for the ρ and ω.

It is interesting to examine these predictions at higher masses where all two-meson channels are open and the process might be dominated by some SU(3) nonet of higher vector particles.[3] The experimental data should be checked for some qualitative indication of the SU(3) selection rule forbidding neutral kaon pair production. This would appear as a suppression of production of neutral kaon pairs relative to charged kaon pairs, resulting from some interference between the contributions of the isoscalar and isovector components of the photon.

Quantitative predictions including effects of SU(3) symmetry breaking can be calculated by assuming various possibilities for coherence or incoherence of the contributions from ρ-like, ω-like and ϕ-like components. The contributions from each photon component to the amplitude for each final state are listed in Table 1.

TABLE I. Annihilation Amplitudes

Photon Component	$A(\pi^+\pi^-)$	$A(K^+K^-)$	$A(K_1K_2)$
ρ	1	1/2	-1/2
ω	0	1/6	1/6
ϕ	0	1/3	1/3

The two-pion amplitude has been normalized to unity.

The predicted branching ratios for the different final states can be calculated under various assumptions regarding the photon components.

These are listed in Table 2.

TABLE II. Branching Ratios

Photon Component Assumptions	$\sigma(K^+K^-)/\sigma(\pi^+\pi^-)$	$\sigma(K_1K_2)/\sigma(\pi^+\pi^-)$
All channels coherent All channels open	1	0
Kaon channels closed for ρ and ω	1/9	1/9
Incoherent ρ, ω and ϕ All channels open	7/18	7/18
Coherent ρ and ω; incoherent ϕ. All channels open.	5/9	2/9

These cases are sufficiently different qualitatively to be of experimental interest. In the absence of isoscalar-isovector interference, the charged and neutral kaon rates are equal. However, even with coherent contributions only from the ω and not from the ϕ there is already a 5/2 ratio of charged to neutral kaons.

Note that symmetry breaking always suppresses the total kaon rate relative to the total pion rate from the equality predicted by SU(3). This is due to the absence of the ϕ-ω interference term, which enhances both charged and neutral kaon pairs.

Recent experimental data[4] at 1.5 - 1.7 GeV show that $\sigma(K^+K^-)/\{\sigma(\pi^+\pi^-) + \sigma(K^+K^-)\} = 0.53 \pm 0.13$. This is consistent with unbroken SU(3), but the broken SU(3) predictions with incoherent ϕ and/or ω are within two standard deviations. It would be very interesting to check the neutral kaon pair production to see if the SU(3) suppression factor is present. Upper bounds on the $K^0\overline{K}^0$ production could be obtained from the inclusive K_1 production, which might be easier to measure experimentally

$$\sigma(e^+e^- \to K^0\overline{K}^0) \leq \sigma(e^+e^- \to K_1 + X) \tag{2}$$

The above discussion also has interesting implications for the application of SU(3) symmetry in various models for deep inelastic processes. It is tempting to assume that SU(3) symmetry is broken primarily by the $K\pi$ mass difference. Thus SU(3) predictions relating kaon and pion production processes should be violated, but predictions involving only pions or only kaons might be better satisfied. This approach fails completely in the present example where SU(3) symmetry breaking drastically effects the ratio of neutral to charged kaon production. The crucial feature is the coherence implicitly assumed in all SU(3) predictions between the contributions of the ρ-like, ω-like and ϕ-like components.

This example suggests another criterion for testing the applications of SU(3) for deep inelastic processes. The photon should be broken down into its ρ-like, ω-like and ϕ-like components and the role of interference terms between these components in any prediction should be carefully considered.. An important effect of SU(3) symmetry breaking could be to cancel all these interference terms and give quite different predictions.

REFERENCES

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